# Lithofacies Discrimination Using Model Based Post Stack Seismic Inversion in 'STD' Field, Niger Delta

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## ABSTRACT

Lithofacies discrimination is important for improved reservoir development and reduction of uncertainties associated with characterizing hydrocarbon reservoirs. In this study, a model driven post stack acoustic impedance inversion was carried out via the integration of a suite of well logs and 3D seismic data acquired from "STD" field in the Niger Delta. The aim was to discriminate the lateral and vertical variations in subsurface rock properties as well as map prospective hydrocarbon zones away from well location. The dataset used comprised the caliper, gamma ray, resistivity, density and compressional sonic logs from a well, and a 3D post stack seismic volume. The methodology entails checkshot correction of the compressional sonic log, extraction of wavelet from the seismic and well data, correlation of well and seismic data, picking of horizons, building of a low-frequency model and execution of a model-driven acoustic impedance inversion. The inversion results reveal three distinct lithofacies (sand, sandy shale and shale) based on acoustic impedance variations. Low acoustic impedance, ranging between 10388 (ft/s) (g/cc) and 11963 (ft/s) (g/cc) was obtained between 1650ms and 1700ms, indicating prospective hydrocarbon-wet sand facies. The results show enhanced stratigraphic disposition of the reservoir for improved interpretation to reduce drilling risk, optimize recovery and make informed economic decisions.

**Keywords:** Acoustic impedance, Model-based Inversion, Lithofacies

## INTRODUCTION

The identification and delineation of reservoir facies form a part of the major challenges encountered by the exploration geoscientist during field planning, appraisal, and development drilling due to the heterogeneity of the subsurface. The characterization of the reservoir plays an important role in the prediction of the reservoir properties as well as the economic potential of an oilfield. A comprehensive study of a producing hydrocarbon reservoir is essential for the development planning of the reservoir and to reduce risk and uncertainty in choosing new drilling locations (Torres and Sen, 2004), and this often requires the integration of seismic and well log data. Seismic inversion is a vital tool that have been utilized by geoscientists for years to reduce risks associated with exploration, development, and production of oil and gas (Barclay *et al.,* 2008). Sheriff (2002) defines inversion as deriving a model from field data to describe the subsurface that is consistent with the data. Seismic Inversion is a process of converting seismic reflection amplitudes to rock properties, particularly acoustic impedance. It is possible due to the fact that seismic waves are reflected at rock interfaces of acoustic impedance contrast, which is the product of density and velocity; and every reflection changes the amplitude of the returned wave. The information obtained from the seismic reflection amplitudes can be used to back out, or invert, the relative impedances of the rock units at different interfaces. By correlating these derived seismic properties with wellbore measurements, well information can be extrapolated to the entire seismic volume for quantitative studies In this work, a model-based seismic inversion technique was used to invert a post-stack seismic data into acoustic impedance property of the subsurface geologic layers in order to provide useful information for delineating lithological units in the study area with a higher confidence limit.

## GEOLOGICAL SETTING

The study area is located within the oil rich province of the Niger Delta. The Niger Delta basin is bordered by the Gulf of Guinea in the south and in the north by the Anambra basin, the Abakaliki uplifts, and the Afikpo syncline. The basin is said to be tertiary in age and consists of three stratigraphically superimposed sequence of lithofacies (Fig. 1) – Akata Formation, Agbada Formation and Benin


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Formation (Doust and Omatsola 1989). The Akata formation is the basal unit of the Niger Delta and it is composed primarily of dark marine shales rich in planktonic foraminifera and assumed to be the source rock of the basin. The overlying Agbada formation is the houses the hydrocarbon bearing reservoir units in the Niger Delta; it is a cyclic sequence of marine and fluvial deposits, consisting of coarse to fine grained, poorly to moderately sorted, unconsolidated to slightly consolidated sandstone with shale intercalations (Short and Stauble, 1967; Weber, 1971; Weber and Daukoru, 1975; Weber, 1986). The Benin Formation which is the uppermost section of the Niger Delta depositional sequence consists mainly of massive, highly porous sandstones with localized clay drapes and thin shale interbeds towards the base of the formation. The basin is characterized by E-W trending syn-sedimentary faulting and folding, with the major structural features described by Evamy *et al.* (1978) as growth faults and rollover anticlines.

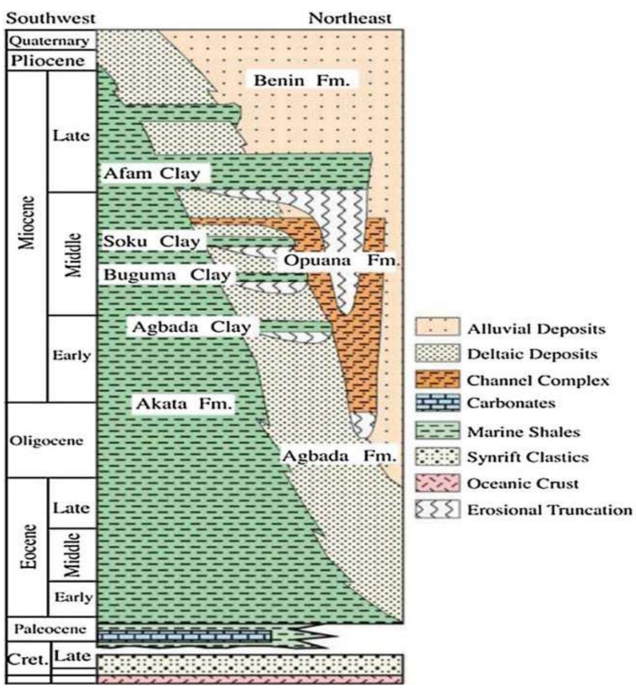


**Figure 1:** Stratigraphic column showing the three formations of the Niger Delta (Lawrence et al; 2002).

## DATA AND METHODOLOGY

The data used for this study comprises a poststack 3D seismic data and a suite of well logs (Fig. 2) from "STD" field in shallow offshore Niger Delta. The methodology adopted for this study is presented in Fig. 3. Using the available checkshot data, the log suite was corrected for the drift of the sonic log (Fig. 4), with the aim of improving seismic to-well tie. A statistical zero-phase wavelet from seismic and well data was extracted and convolved with the reflectivity from the well, to generate a synthetic seismogram at well location. Time shift was applied to the synthetic trace in order to obtain a good match with the seismic, giving very high correlation coefficient and minimal errors. This well-to-seismic process resulted in the correction of the compressional sonic log at the well location. Horizons marking formation tops and bottoms with sharp continuous seismic amplitude traces were picked on the seismic to provide prior geological information for the inversion process. Due to the band-limited nature of the seismic data, a high cut filter was applied to the broadband well logs in order to build a low frequency impedance model generated using P-impedance log calculated from the updated P-wave sonic and density logs. The initial model was extrapolated laterally to the seismic data using the interpreted horizons as a guide. The model based inversion was applied to the entire poststack 3D seismic volume to obtain an impedance model by iteratively solving the reflectivity that will give a least-square fit and minimize errors between the synthetic traces and the actual seismic data.

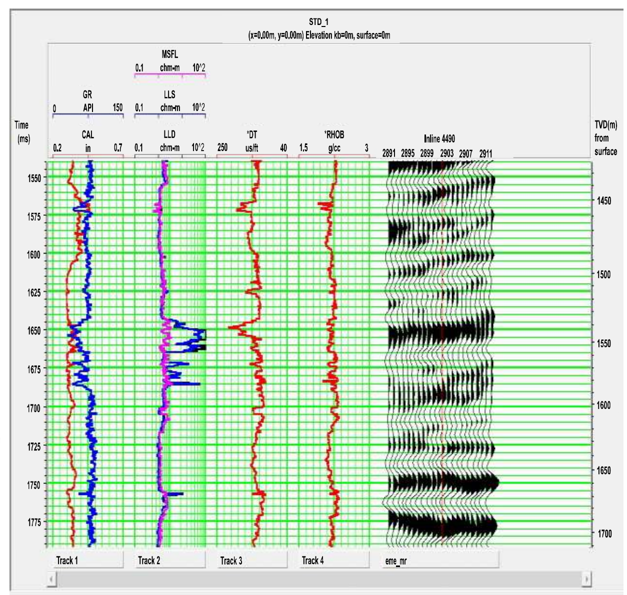


**Figure 2:** Display of well log and Seismic data.

## RESULTS AND DISCUSSION

The result of the inverted impedance volume is presented in Fig. 6. The figure shows lateral and vertical variations in acoustic impedance which depicts differences in lithofacies. Three lithofacies were revealed and interpreted as sand, sand-shale and shale. The low impedance zone from a time slice of 1643.27-1723.98ms is suggestive of a porous and permeable sand facie. The shale facie is

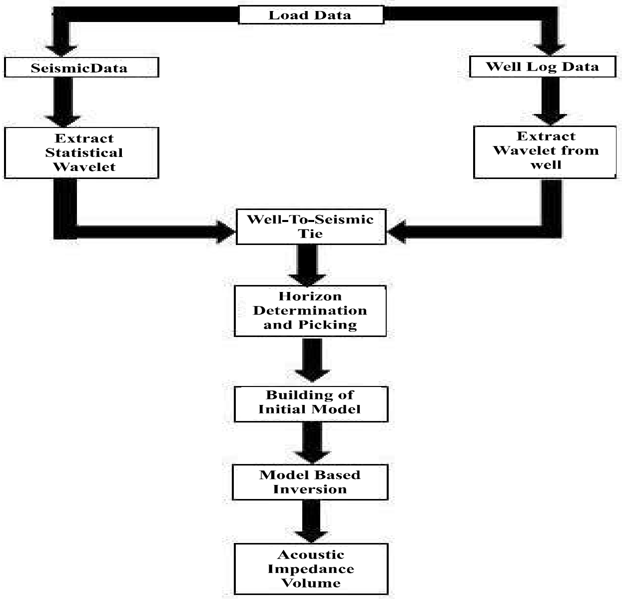


**Figure 3:** Model Based Post Stack Seismic Inversion Workflow.

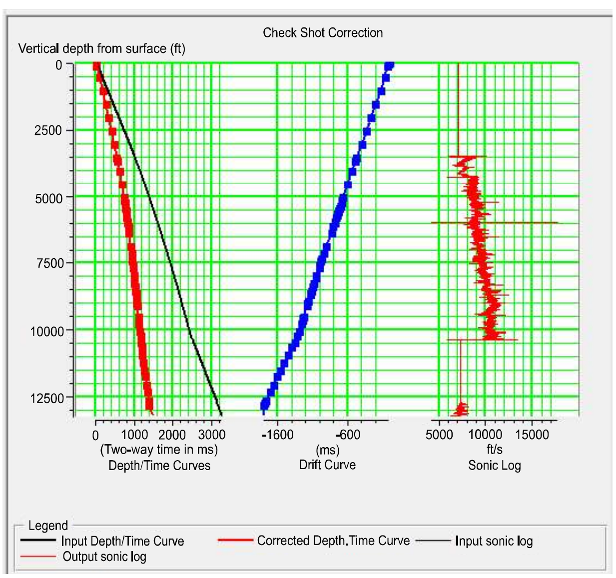


**Figure 4:** Check Shot Correction of the P-wave Sonic Log.

characterized by a high impedance zone, while the variability in impedance between sand and shale indicates a possible sand-shale facie unit. Overlying the low impedance sand (blue arrow) is a variable impedance as shown by the colour band (red to light blue with brown) seen at this interval suggests a dense layer of impermeable shale unit which could act as a seal for a probable hydrocarbon wet sand. Beneath the sand facie from a time window of 1715-1778ms, the acoustic impedance is dominantly high (brown through blue to pink colours) and this suggests the presence of shale lithofacie (see black arrow on Fig. 6). This is consistent with the paralic sequence of the Agbada formation noted by Doust and Omatsola (1989). Slightly high impedance values (yellow to red colours) at the upper and lowermost section of the impedance volume indicates a sand-shale facie.

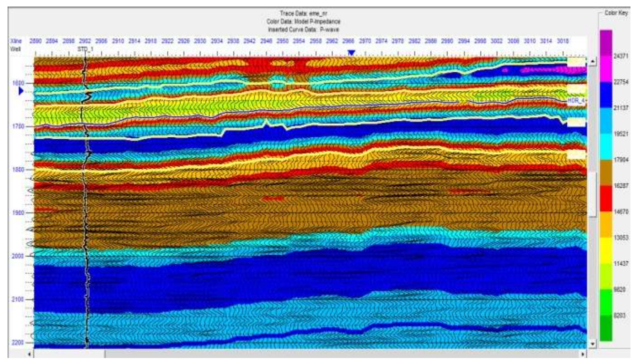

**Figure 5:** Low Frequency Initial Model.

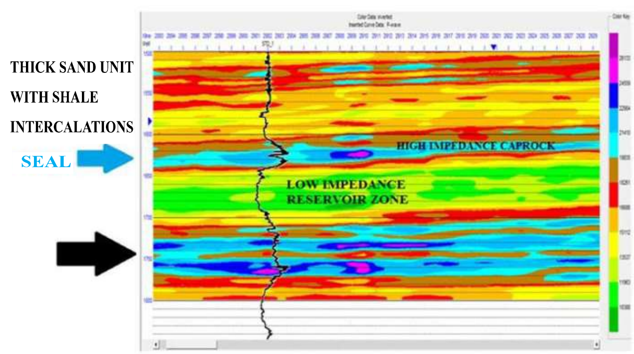


**Figure 6:** Interpreted Inverted Acoustic Impedance Volume.

## CONCLUSIONS

In this study, we made efforts to carry out post stack seismic inversion on a 3D seismic data acquired in the Niger Delta. Specifically, the study was carried out to investigate lateral and vertical variations in rock property in the area. The results show that acoustic impedance inversion can discriminate lithofacies.

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